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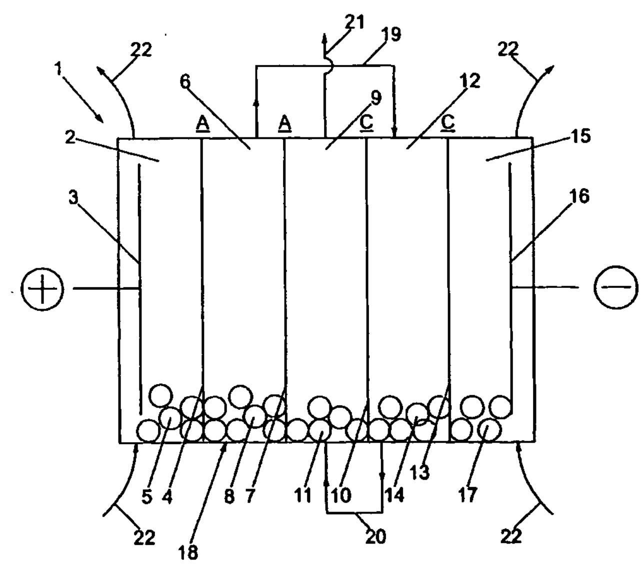
(54) Title: ELECTRODEIONISATION APPARATUS



(57) Abstract: An electrodeionisation apparatus comprising, successively: means defining an anode chamber, means defining one or more anion exchange chambers, means defining one or more mixed exchange chambers, means defining one or more cation exchange chambers, and means defining a cathode chamber, the anion, mixed and cation exchange chambers providing a flow path for water to be purified, is described. The present invention incorporates advantages of both separate resin bed and mixed resin bed technology.

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Electrodeionisation Apparatus

The present invention relates to an electrodeionisation apparatus for purifying water and method therefor.

Apparatus and methods for electrodeionisation to provide purified water are well known, see for example our GB-A-2311999 and US 4687561. Generally, water to be purified is passed along a deionising path set between an anode and a cathode. The application of a potential difference between the anode and cathode causes anions and cations in the impure water to migrate towards their respective attracting electrodes through perm-selective membranes.

In general, such apparatus has the chambers for exchanging anions and cations juxtapositioned so that the anions and cations removed from the water being purified both travel towards one or more 'concentrating' chambers, through which a desalting

stream flows to remove the unwanted anions and cations.

It is an object of the present invention to provide a simplified electrodeionisation apparatus and method.

According to one aspect of the present invention, there is provided an electrodeionisation apparatus comprising, successively:

means defining an anode chamber,
means defining one or more anion exchange chambers,
means defining one or more mixed exchange chambers,
means defining one or more cation exchange chambers, and
means defining a cathode chamber,

the anion, mixed and cation exchange chambers providing a flow path for water to be purified.

By locating the or each anion exchange chamber next to the anode chamber, and locating the or each cation exchange chamber next to the cathode chamber, the apparatus of the present invention provides an opposite or reverse flow-path for exchanged anions and cations than prior apparatus. The exchanged anions and cations in the water being purified are directly attracted to neighbouring electrodes, rather than being attracted to distal electrodes located across opposing exchange chambers of prior electrodeionisation apparatus.

In one embodiment of the present invention, the apparatus involves one anion exchange chamber and one cation exchange chamber.

Located between the chambers are perm-selective membranes as are known in the art. Those membranes located between the or each central mixed exchange chamber and the cathode chamber should be cation membranes, and those membranes located between the or each mixed exchange chamber and the anode chamber should be anion membranes.

Preferably, the or each anion exchange chamber partly, substantially or wholly contains anion exchange material, and the or each cation exchange chamber partly, substantially or wholly contains cation exchange material.

Preferably, the anode chamber partly, substantially or wholly contains ion exchange material, preferably cation exchange material. Preferably, the cathode chamber, partly, substantially or wholly contains ion exchange material, more preferably cation exchange material. Also preferably, the or each mixed exchange chamber partly, substantially or wholly contains mixed ion exchange material. Ion exchange materials are known in the art, one example being resin beads.

The anode and cathode chambers are preferably flushed with a desalting stream such as water to elute ions from the system as concentrate.

In another embodiment of the present invention, water to be purified is firstly passed through an anion exchange chamber of the apparatus, then through a cation exchange chamber, and subsequently through a mixed exchange chamber.

Alternatively, water to be purified is passed through a cation exchange chamber, then through an anion exchange chamber, and subsequently through a mixed exchange chamber.

Where apparatus of the present invention involves two or more anion exchange chambers and/or two or more cation exchange chambers and/or two or more mixed exchange chambers, then impure water flow path could be directed through subsequent anion exchange chambers and/or subsequent cation exchange chambers and/or subsequent mixed exchange chambers in the same or any suitable or relevant order.

In a third embodiment of the present invention, water to be purified by the present apparatus is combined with already purified water, so reducing, by dilution, the load on the exchange materials. The already purified water may be provided from a separate source, or be provided by re-circulating outflow from the present apparatus, which outflow could be temporarily held in a reservoir such as a holding tank.

According to a fourth embodiment of the present invention, the anion, cation and mixed exchange

chambers are relatively thick compared with chambers of prior art electrodeionisation apparatus. The simplicity of the present invention allows thicker chambers and beds of ion exchange materials to be used, compared with the conventional view that thinner beds are necessary to maintain electric current flow thereacross.

The present invention also extends to a 'multiple' unit still only involving one set of electrodes. For example, the unit could be arranged: anode (chamber), anion, mixed, cation, concentrate…, anion, mixed, cation, concentrate…, anion, mixed, cation, cathode.

According to a second aspect of the present invention, there is provided a method of electrodeionisation comprising causing or allowing water to be purified to flow through an anion exchange chamber neighbouring an anode chamber, followed by flow through a cation exchange chamber neighbouring a cathode chamber, or vice versa, followed by flow through a mixed exchange chamber located between the anion exchange chamber and the cation exchange chamber.

The method of the present invention could use electrodeionisation apparatus as described above. In the method of the present invention, the water to be purified could be pre-mixed with a proportion of already purified water.

In general, water may be passed through each chamber independently, allowing different flow rates, including no flow, at different times.

An embodiment of the present invention will now be described by way of example only, and with reference to the accompanying drawing, Figure 1, which is a schematic cross-sectional side view of apparatus according to the present invention.

Referring to the drawing, Figure 1 shows an electrodeionisation apparatus in the form of a stack (1). The stack (1) has five chambers. The first chamber (2) is an anode chamber bounded on one side by an anode (3) and on the other by an anion membrane (4). The anode chamber (2) contains cation exchange resin beads (5). Juxtaposed the anode chamber (2) is an anion exchange chamber (6) bounded on one side by the anion membrane (4), and on the other side by a second anion membrane (7). The anion exchange chamber (6) contains anion exchange resin beads (8). Next to the anion exchange chamber (6) is a mixed exchange chamber (9), bounded by the second anion membrane (7) and a cation membrane (10). This chamber (9) contains mixed ion exchange resin beads (11).

Juxtaposed the mixed exchange chamber (9), there is a cation exchange chamber (12) bounded by the cation membrane (10), and a second cation membrane (13). The cation exchange chamber (12) contains cation exchange resin beads (14).

Juxtaposed the cation exchange chamber (12) lies a cathode chamber (15) bounded by the second cation exchange membrane (13) and a cathode (16). The cathode chamber (15) contains cation exchange resin (17).

The nature and form of the electrodes, membranes and ion exchange materials are all known in the art.

In use, impure feed water (18) enters the stack (1), and firstly enters the anion exchange chamber (6). The anion exchange resin beads (8) in this chamber (6) replace the anions in the feed water with hydroxide ions from the resin beads (8). The anions then move towards and through the anion exchange membrane (4) to the anode chamber (2). The driving force for this movement is an electrical potential placed between the anode (3) and cathode (16). The feed water (19) exiting this chamber (6) is then passed into the cation exchange chamber (12), where the cation exchange resin beads (14) exchange cations in the feed water for hydrogen ion. The cations then move towards and through the cation exchange membrane (13) to the cathode chamber (15).

The water (20) exiting this chamber (12) is then passed into the mixed resin chamber (9). The mixed resin beads remove both anionic and cationic ions that have passed through the first two chambers (6, 12). Ions removed in the mixed exchange chamber (9) pass through the relevant ion exchange membranes (7, 10) to the single exchange chambers, where they, as

well as ions exchanged therein, pass through the relevant ion exchange membranes into the electrode compartments.

From the mixed chamber (9) final product water (21) is obtained for use.

The electrode compartments (2, 15) are flushed with water to elute the ions from the system as concentrate (22). This flow may be in series or in parallel.

In an alternative arrangement, feed water could firstly be passed into the cation exchange chamber (12), followed by the anion exchange chamber (6), before being passed into the mixed exchange chamber (9). This alternative flow-path arrangement also allows the removal of precipitative cations such as calcium before they reach the anion exchange material (8) and anion membranes (4, 7) on which they are likely to precipitate. As these ions pass into the cathode exchange chamber (12), it is preferable to maintain a low pH in the cathode exchange chamber (12) and to feed the cathode chamber (15) with water, or acid, devoid of precipitative ions.

The product water (21) exiting the mixed exchange chamber (9) of the present invention has been found to be of low ionic content. Indeed, the flow rate and purification achieved by the present invention is comparable with prior art EDI apparatus, which

generally involves a significantly more complex arrangement of chambers.

In another arrangement of the present invention, the feed water (18) is pre-mixed with a proportion of already purified water (21). By diluting the load (i.e. concentration of impure ions to be removed from the water), a higher flow rate through the apparatus can be achieved.

Indeed, a ratio of 10:1 of already purified water:impure water allows a flow rate of at least 2/3 litres per minute through the apparatus shown in Figure 1. The already purified water could be supplied from a separate source, or be re-circulated product water (21) from the present apparatus.

The following test data using a design of stack as shown in Figure 1 confirms the benefit of the present invention:

Example 1

A stack with internal plate dimensions 150 mm x 66 mm x 15 mm was operated on a blend of reverse osmosis permeate and deionised water. With a feed of conductivity 18.2 μS/cm (adjusted to 25°c) the stack purified 0.55 litres per minute to a conductivity of 0.073 μS/cm when a current of 1.3 amps was applied between the electrodes. With a feed of 7.2 μS/cm, 1.37 litres per minute were purified to 0.092 μS/cm at 1.3 amps.

Example 2

A stack with dimensions 135 mm x 68 mm x 10 mm was operated recirculating from a tank. Water was intermittently taken off after the stack and extra make up was fed to the stack from a reverse osmosis membrane. The applied current was 3.16 amps. When the reverse osmosis unit was operating the feed to the stack was 12.5 µS/cm and this was purified at a rate of 1.95 litres per minute to 0.062 µS/cm. When recirculating from the tank the feedwater reduced in conductivity to 0.32 µS/cm at which time the product water was 0.057 µS/cm.

The present invention incorporates advantages of both separate resin bed and mixed resin bed technology. Separate resin beds are beneficial for removing known amounts of defined ionic impurity types, both anion and cation, and the current passing through that resin bed can be utilised in removing solely that type of ion.

If the feed water is first passed through a cation exchange resin bed, cations can be removed from the solution causing a reduction in the solution pH. Similarly, an anion resin bed will increase the pH. Changes in pH help to prevent bacterial growth, and may also be used to prevent precipitation, or increase the ionic nature of weakly charged species.

Meanwhile, mixed resin beds have been noted to handle high flow rates of water whilst still achieving high levels of purification.

The present invention has several further advantages. It provides a compact purification unit using a single set of electrodes. It is of simple form, allowing simplified manufacturing thereof, with less complication and therefore with reduced risk of potential breakdown.

As mentioned before, water may be passed through each chamber independently, allowing different flow rates, including no flow, at different times.

Also, the number of chambers of the present invention, possibly being only five, are less than many prior art apparatus, thus reducing the problems of back pressure on the feed water, and allowing a faster flow rate therethrough. The use of relatively thick chambers in the present invention also reduces the feed water back pressure.

Furthermore, feed water through the present invention does not pass through the anode or cathode chambers as occurs in some prior art apparatus, thereby avoiding the problem of gas in the product water.

Also, the present invention aids removal of weakly ionised species, and can be used in a manner to inhibit precipitative fouling.

Claims

1. An electrodeionisation apparatus comprising, successively:

means defining an anode chamber,
means defining one or more anion exchange chambers,
means defining one or more mixed exchange chambers,
means defining one or more cation exchange chambers, and
means defining a cathode chamber,

the anion, mixed and cation exchange chambers providing a flow path for water to be purified.

2. Apparatus as claimed in Claim 1 involving one anion exchange chamber and one cation exchange chamber.

3. Apparatus as claimed in Claim 1 or Claim 2 wherein two or more of the chambers are divided by perm-selective membranes.

4. Apparatus as claimed in Claim 3 wherein any membrane located between the or each central mixed exchange chamber and the cathode chamber is a cation membrane.

5. Apparatus as claimed in Claim 3 or Claim 4 wherein any membrane located between the or

each mixed exchange chamber and the anode chamber is an anion membrane.

6. Apparatus as claimed in any one of the preceding Claims wherein the or each anion exchange chamber partly, substantially of wholly contains anion exchange material.

7. Apparatus as claimed in any one of the preceding Claims wherein the or each cation exchange chamber partly, substantially or wholly contains cation exchange material.

8. Apparatus as claimed in any one of the preceding Claims wherein the anode chamber partly, substantially or wholly contains ion exchange material.

9. Apparatus as claimed in any one of the preceding Claims wherein the cathode chamber, partly, substantially or wholly contains ion exchange material.

10. Apparatus as claimed in Claim 8 or Claim 9 wherein the ion exchange material is cation exchange material.

11. Apparatus as claimed in any one of the preceding Claims wherein the or each mixed exchange chamber partly, substantially or wholly contains mixed ion exchange material.

12. Apparatus as claimed in any one of Claims 6 to 11 wherein the ion exchange material is resin beads.

13. Apparatus as claimed in any one of the preceding Claims wherein the or each anion, cation and/or mixed exchange chambers are between 5-20mm wide.

14. A method of electrodeionisation comprising causing or allowing water to be purified to flow through an anion exchange chamber neighbouring an anode chamber, followed by flow through a cation exchange chamber neighbouring a cathode chamber, followed by flow through a mixed exchange chamber located between the anion exchange chamber and the cation exchange chamber.

15. A method of electrodeionisation comprising causing or allowing water to be purified to flow through a cation exchange chamber neighbouring a cathode chamber, followed by flow through an anion exchange chamber neighbouring an anode chamber, followed by flow through a mixed exchange chamber located between the anion exchange chamber and the cation exchange chamber.

16. A method as claimed in Claim 14 or claim 15 wherein the flow of water through each chamber is independent of other flows.

17. A method as claimed in any one of Claims 14 to Claim 16 wherein the anode and cathode chambers are flushed with a desalting stream.

18. A method as claimed in any one of Claims 14 to 17 which involves two or more anion exchange chambers and/or two or more cation exchange chambers and/or two or more mixed exchange chambers, wherein the water to be purified flows through one or more subsequent anion exchange chambers and/or one or more subsequent cation exchange chambers and/or one or more subsequent mixed exchange chambers in the same or any suitable or relevant order.

19. A method as claimed in any one of Claims 14 to 18 wherein the water to be purified is combined with purified water prior to electrodeionisation.

20. A method as claimed in Claim 19 wherein the water to be purified is combined with water provided by outflow product of the method of Claims 14 to 18.

21. A method as claimed in any one of Claims 14 to 20 wherein apparatus as claimed in any one of Claims 1 to 13 is used.

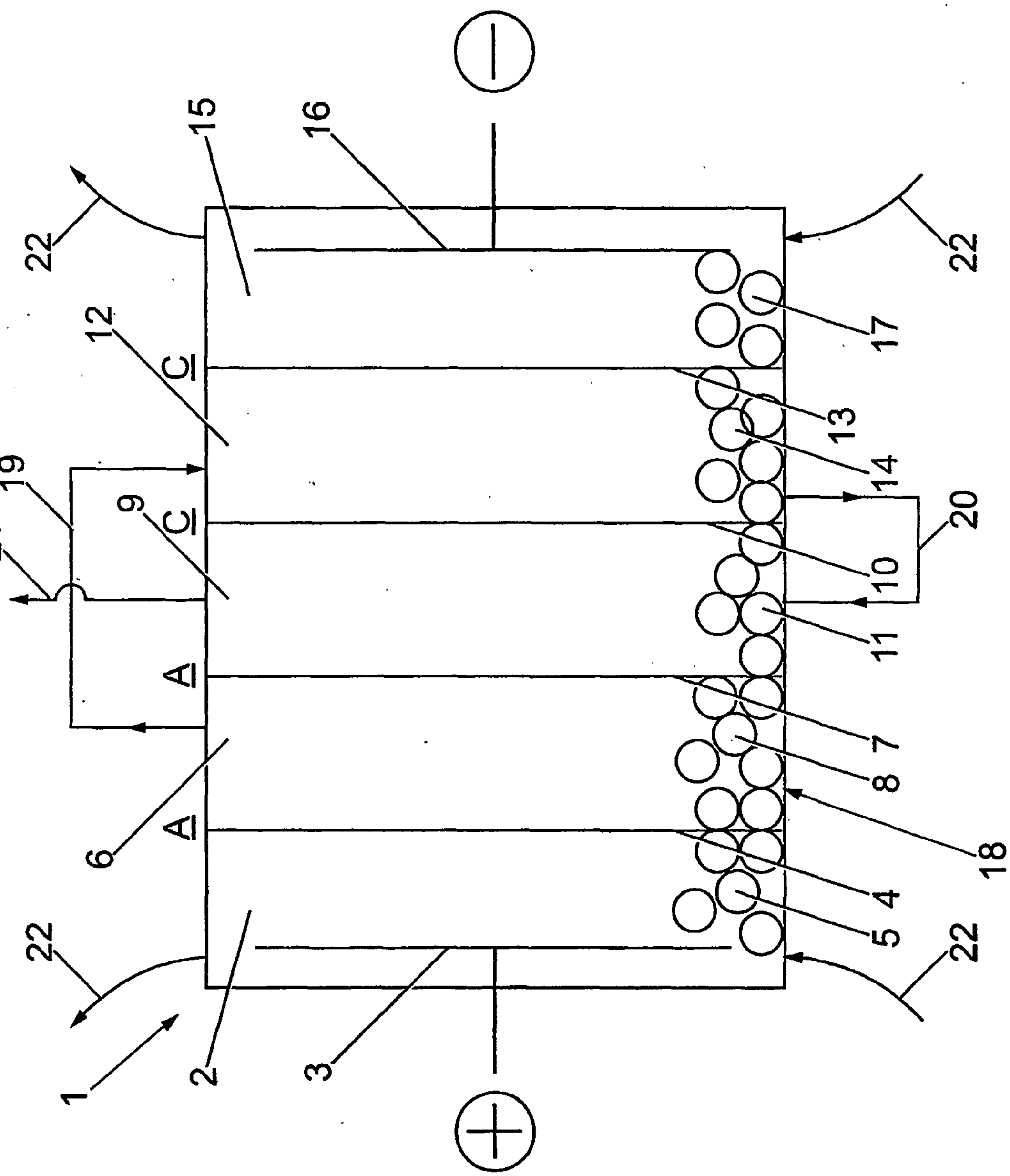

Fig. 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/02967

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C02F1/469 B01D61/48 B01J47/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C02F B01D B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 32 38 280 A (LIEBER HANS WILHELM PROF DR IN) 19 April 1984 (1984-04-19) claims 1-3,5; figures 1,2,5	1-21
A	GB 2 311 999 A (ELGA GROUP SERVICES LTD) 15 October 1997 (1997-10-15) cited in the application claims 1,5; figure 1	1-21
A	US 4 687 561 A (KUNZ GERHARD) 18 August 1987 (1987-08-18) cited in the application claim 1.16; figure 1	1-21
A	US 3 869 376 A (TEJEDA ALVARO R) 4 March 1975 (1975-03-04) figure 5	1-21

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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